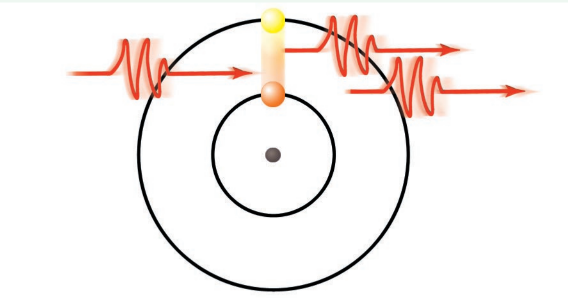
PHYSICS & TECHNOLOGY

TARGET SKILLS

- Hypothesizing
- Analyzing and interpreting

Atoms and Lasers

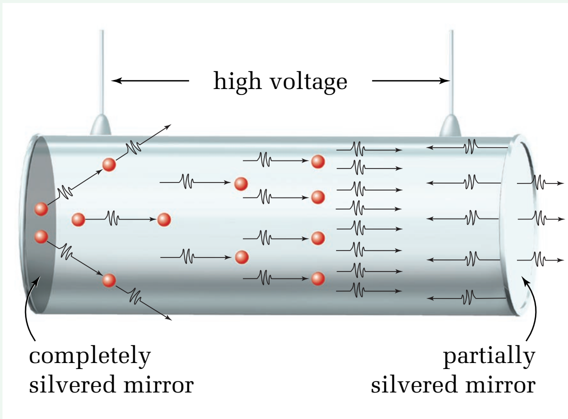
A thorough understanding of the energy levels of electrons in atoms and of transitions between these states was necessary before anyone could even imagine that a laser could be developed. Another critical property of electrons that was necessary in order to develop lasers was predicted by Einstein in 1917 — the stimulation of emission of a photon. As shown in the diagram, if an electron is in an excited state (that is, in a higher energy level), a photon with an energy level equal to the difference in allowed energy levels will stimulate the electron to drop to the lower energy level and emit another identical photon. In addition, the two photons are perfectly in phase.



If more electrons exist in the excited state than in the ground state, it is more probable that a photon will stimulate an emission instead of being absorbed. Two conditions are necessary in order to create and maintain this condition. Normally, most electrons are in the ground state at room temperature, so a stimulus is needed to excite the electrons. This stimulus can be provided by a high voltage that will accelerate free electrons, and then collisions with atoms will excite their electrons. The process is called "optical pumping."

If the excited electrons spend a longer than normal time in the excited state, stimulated emission will be more probable than spontaneous emission. This condition is met by selecting atoms of elements that have specific energy levels called the "metastable state." Electrons remain in metastable states for about 10^{-3} s, rather than the normal 10^{-8} s.

A typical gas laser tube is shown in the diagram. A high voltage excites the electrons in the gas, maintaining more atoms in an excited state than the ground state. As some photons are emitted spontaneously, they stimulate the emission of other photons. The ends of the laser tube are silvered to reflect the photons. This reflection causes more photons to stimulate the emission of a very large number of photons. Any photons that are not travelling parallel to the sides of the tube exit the tube and do not contribute to the beam. One end of the tube is only partially reflecting, and a fraction of the photons escape. These escaping photons have the same wavelength and frequency and are all in phase, creating a beam of what is called "coherent light."



Analyze

1. The word "laser" is an acronym for "light amplification by stimulated emission of radiation." Explain the significance of each term in the name.
2. Laser beams remain small and do not spread out, as does light from other sources. Based on the unique characteristics of laser light, try to explain why the beams do not spread out.
3. List as many applications of laser as you can.

The years from 1900 to 1930 were exciting ones in physics. No longer could physicists speak of waves and particles as separate entities — the boundary between the two became blurred. The long-standing Dalton model of the atom gave way to the Thomson model, which was soon usurped by the Rutherford model and, soon thereafter, by the Bohr model. Eventually, all models that represented electrons as discrete particles yielded to the quantum mechanical model described by the Schrödinger wave equation.

Today, the wave equation is still considered to be the most acceptable model. In fact, physicists have been able to show that the wave equation can give information about the nucleus and particles that was not known to exist when Schrödinger presented his equation. In the next chapter, you will learn about properties of the nucleus and particles that exist for time intervals as small as 10^{-20} s.

12.3 Section Review

1. C Discuss the similarities and differences between Dalton's model of the atom and J.J. Thomson's model of the atom.
2. K/U What surprising observation did Rutherford and Geiger make that motivated Rutherford to define a totally new model of the atom?
3. K/U In what way did Rutherford's nuclear model of the atom conflict with classical theory?
4. C Explain how experimentally observed spectra of atomic hydrogen helped Bohr develop his model of the atom.
5. K/U According to Bohr's model of the atom, what property of electrons in atoms must be quantized?
6. K/U List the four postulates on which Bohr based his model of the atom.
7. C Explain how Coulomb's law played a role in the determination of the Bohr radius.
8. C Describe the two features of the emission spectrum of atomic hydrogen that revealed a flaw in Bohr's model of the atom.
9. K/U How did Dirac improve Schrödinger's wave equation?
10. K/U What is a wave function and what type of information does a wave function provide about atoms?
11. K/U List and define the four quantum numbers.
12. C Balmer's work on the spectrum of hydrogen helped Bohr to modify Rutherford's model of the atom. Explain how he did this.
13. K/U Write down Rydberg's modification of Balmer's formula and define the terms.
14. K/U What can cause an electron in the Bohr model to "jump" to a higher energy level?
15. K/U Explain the term "principal quantum number."

UNIT PROJECT PREP

Inquisitive minds following unexpected results often lead to advances in our scientific understanding of the universe.

- Do you believe, and can you support, the idea that unexpected experimental results have contributed more to scientific discovery than any other means?
- Which theory, special relativity or quantum mechanics, was received with more skepticism by the general public of the time? Suggest reasons.